

VITAMINS IN SUGARCANE JUICE AND IN SOME CANE-JUICE PRODUCTS¹

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INTRODUCTION

In addition to the commonly accepted food value of sugarcane sirup and molasses as carbohydrates and their place in supplying characteristic flavors and variety in the diet, it was formerly believed in certain sections where cane sugar was manufactured that the juice of the cane was particularly healthful and even had some remedial properties. In the early days of the sugar industry in this country the sugar mill was regarded as a very healthful place to work. The evaporation of the cane juice was carried out in large open cauldrons or kettles, and the steam and vapors escaped into the building. The breathing of these vapors was considered beneficial. Large quantities of the cane juice were drunk, and other products of the sugar factory were included in the diet. Whether the reported beneficial results were real or fancied, however, they contribute an added interest to the study of the vitamin content of sugarcane juice.³

As far as the authors are aware but little work has been done on the vitamin content of fresh sugarcane juice. Delf⁴ found that sugarcane juice had no antiscorbutic value.

In this paper are presented the results of some experiments carried out to determine the vitamin B⁵ and vitamin D potency of the juice of sugarcane. Some preliminary tests were also made for vitamin A. The juice used was obtained from three lots of sugarcane stalks shipped at widely different times and from different sections of the country.

In addition to estimating the vitamins in the juice obtained by crushing whole cane stalks in a laboratory-size sugarcane mill, a comparison was made of the vitamin B value of the juice thus expressed with that obtained by subjecting the bagasse from the small mill to the much higher pressure of a hydraulic press. Comparison was also made of the vitamin B potency of juice obtained from different parts of the same cane stalks. For this purpose juice

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² The authors wish to acknowledge their indebtedness to H. S. Paine and R. T. Balch, of the Carbohydrate Division of this bureau, for the analyses of the samples of the cane juice used in this investigation and for supplying the samples of the cane-juice products studied; also to J. F. Brewster for having some of the sugarcane collected and shipped, and to J. P. Divine for technical assistance in carrying out the experimental work.

³ The writers are indebted for the above information to C. A. Browne, at whose suggestion the work described in this paper was undertaken.

⁴ DELF, E. M. STUDIES IN EXPERIMENTAL SCURVY, WITH SPECIAL REFERENCE TO THE ANTISCORBUTIC PROPERTIES OF SOME SOUTH AFRICAN FOODSTUFFS. *Lancet* 202: 576-578. 1922.

⁵ Inasmuch as some of the data presented in this paper were obtained before the multiple nature of the water-soluble vitamin B fraction was recognized, the term "vitamin B" has been used in the old sense to refer to the vitamin B complex.

obtained from the upper third and lower third portions of the cane was used. Several products manufactured from sugarcane juice were also examined. These included cane sirup, different samples of blackstrap molasses, and cane cream.

EXPERIMENTAL DATA

VITAMIN B IN SUGARCANE JUICE

The juice used for these experiments was obtained from sugarcane of the 1926 crop, shipped in cold storage from Florida. As soon as possible after arrival the canes were crushed in a laboratory-size sugarcane mill, and the juice obtained was filtered through two thicknesses of cheesecloth. The fairly clear juice was then distributed into a large number of small wide-mouth bottles and placed in cold storage at a temperature below freezing. The frozen juice was taken out of one bottle at a time as needed and was allowed to liquefy at room temperature. The quantities required daily for the feeding experiments were measured out by means of a pipette.

A sample of the freshly expressed juice was analyzed in the carbohydrate division of this bureau. The results are as follows:

| | | |
|-----------------------------------------------------|------------|-------|
| Brix, corrected to 20° C..... | degrees.. | 14.64 |
| Direct polarization, 20° C..... | do..... | 9.73 |
| True sucrose (invertase method)..... | per cent.. | 9.45 |
| Solids (by drying)..... | do..... | 13.17 |
| Invert sugar (Meissl and Hiller method)..... | do..... | 4.13 |
| Apparent purity, $9.73 \times 100 \div 14.64$ | do..... | 66.46 |
| True purity, $9.45 \times 100 \div 13.17$ | do..... | 71.76 |

The juice was tested for vitamin B by both the curative and the prophylactic methods. In the curative tests young albino rats were fed a vitamin B free ration consisting of casein, 20 parts; Osborn and Mendel's Salt Mixture IV, 5 parts; butterfat, 15 parts; and cornstarch, 60 parts. When evidence of vitamin B deficiency was manifested the cane juice was fed at definite levels daily apart from the basal ration. The rats were kept in individual cages having raised screen bottoms. The prophylactic tests were similarly conducted except that the cane juice was fed from the start. The results are shown graphically in Figure 1. Lot 1 consisted of two rats used for controls. Each curve of the other four lots represents the average weight of four rats fed the quantities of juice indicated on the chart. The rats of lots 2 and 3 were given the juice from the beginning of the experiment. In the curative tests with rats of lots 4 and 5, the period during which the juice was fed is indicated in each curve by the broken line.

On account of the difficulty of getting the animals of lot 2 to take as much as 20 c. c. of juice daily, the juice was concentrated to one-fourth of its original volume by evaporation at low temperature under diminished pressure. Of this product 5 c. c. was fed daily. From the results shown it appears that 15 c. c. of the cane juice fed daily fell short of supplying enough vitamin B to maintain weight, but that 20 c. c. was sufficient to promote growth at a fair rate for at least 60 days. Some of the rats of each lot did not always take all the juice given them, but it is believed that this did not significantly affect the final average results.

A previous shipment of cane of the 1924 crop had been received from Louisiana. This cane was superior in size, appearance, and in content of juice to that obtained from Florida. On account of unavoidable circumstances it was not possible to study the vitamins in the juice of this cane to the extent that had been planned. However, the curve in Figure 2, which represents the average weight of four

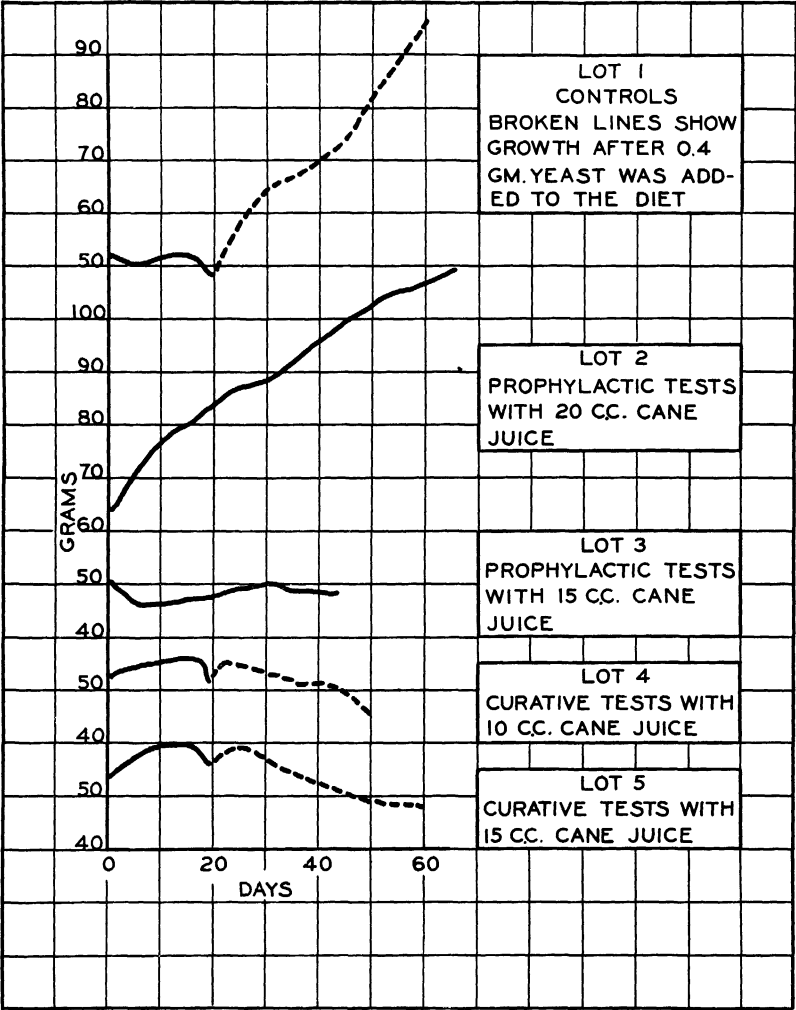


FIGURE 1.—Growth of rats when fed prophylactic and curative doses of cane juice as sources of vitamin B as compared with that of rats fed yeast

rats, shows that the juice from this lot of cane contained more vitamin B than did that of the cane obtained from Florida. Ten cubic centimeters daily of the juice was sufficient to enable the rats to resume growth with an average gain in weight of 15 gm. in 35 days, as indicated by the broken line in the curve. The composition of the basal diet was as follows: Meat residue, 18 gm.; Salts IV, 5 gm.; butterfat, 15 gm.; cornstarch, 62 gm.; making a total of 100 gm.

VITAMIN D IN SUGARCANE JUICE

Tests for vitamin D were made on the juice from the 1926 Florida sugarcane (previously referred to) by means of the "line test".⁶ One lot of four rats was brought to a rachitic condition by feeding them for 25 days Steenbock's rachitic ration No. 2965, consisting of yellow corn, 76 parts; wheat gluten, 20 parts, calcium carbonate, 3 parts; and sodium chloride, 1 part. The animals were then given daily 10 c. c. of the cane juice for 15 days. At the end of the period the degree of calcification induced in the radii of the rachitic animals was observed. A trace of calcification of the rachitic metaphyses was noted in the case of one rat. The others gave negative results.

VITAMIN A IN SUGARCANE JUICE

Preliminary tests for vitamin A indicated the presence of but little of this vitamin. Consequently, these studies were not continued further.

VITAMIN B IN SUGARCANE JUICE EXPRESSED AT DIFFERENT PRESSURES

The juice used in the following experiments was obtained from sugarcane of the 1927 crop sent from Franklin, La. Before shipment

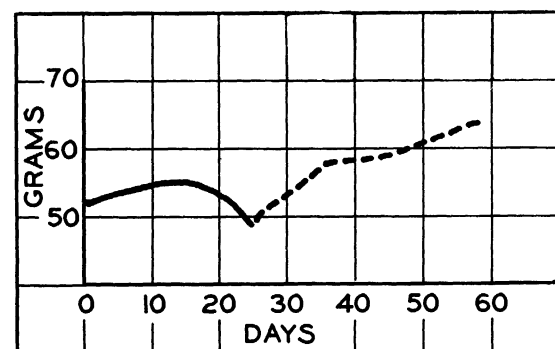


FIGURE 2.—Growth of rats when fed Louisiana cane juice of the 1924 crop as a source of vitamin B

the behavior of the experimental rats on the basal ration used when different levels of yeast furnished vitamin B. The results obtained may also serve as a basis of reference by which the responses of the animals to the sugarcane products tested in the experiments hereafter described can be compared. The vitamin B free basal ration consisted of casein, 18 parts; Osborne and Mendel's Salt Mixture IV, 4 parts; agar, 2 parts; cod-liver oil, 2 parts; and dextrin, 74 parts.

Figure 3 shows the growth response of the animals to different levels of yeast fed as a source of vitamin B. Each curve represents the average weight of four male rats. Although 0.4 gm. of yeast per day permitted growth at a rapid rate, an increased amount of yeast produced better growth. The quantity fed daily is indicated on the chart. On the basal diet used control rats receiving no vitamin B usually

the ends of the stalks were paraffined partially to protect them from deterioration. The shipment included 100 pounds each of stalks representing the upper third and lower third portions of the cane and 200 pounds of whole cane stalks.

Preliminary to the feeding experiments described later it was desired to ascertain

⁶ MCCOLLUM, E. V., SIMMONDS, N., SHIPLEY, P. G., and PARK, E. A. STUDIES ON EXPERIMENTAL RICKETS. A DELICATE BIOLOGICAL TEST FOR CALCIUM-DEPOSITING SUBSTANCES. Jour. Biol. Chem. 51: 41-49, illus.

cease to gain in weight about the tenth day, and almost invariably lose weight rapidly after the fifteenth day.

Ten kilograms of the whole cane stalks were put through a laboratory-size sugarcane mill. The bagasse (5,150 gm.) was cut rather fine in a feed cutter, and pressed in a large Bushnell press, without use of maceration water, until all the juice that could be expressed was removed. The residual bagasse was then further pressed in a hydraulic press up to a pressure of 2,400 pounds per square inch. A total extraction of 70.6 per cent was obtained, of which 4.8 per cent was removed by the hydraulic press. As it was desired to compare only the juice expressed in the roller mill with that obtained from the hydraulic press, the intermediate fraction removed by the Bushnell press was discarded. The two fractions of the juice were filtered through two thicknesses of cheesecloth, and concentrated by evaporation under reduced pressure to one-fourth of the original volume. The concentrated product was stored at low temperature. The results of analyses of the high and low pressure juices are presented in Table 1.

As shown in Figure 4, the vitamin B content of the juice obtained at the higher pressure was much greater than that of any other sugarcane juice tested. Each curve represents the average weight of four male rats fed daily, apart from the basal ration, quantities of the concentrated product corresponding to the number of cubic centimeters of the original juice indicated at the right of the chart. The curves of lots 14 and 15 show that the high-pressure juice is about twice as potent in vitamin B as the other juice. A comparison of the curves in this chart with those in Figure 3 shows that 10 c. c. of the high-pressure juice was approximately equal to 0.15 gm. of dried yeast as a source of vitamin B.

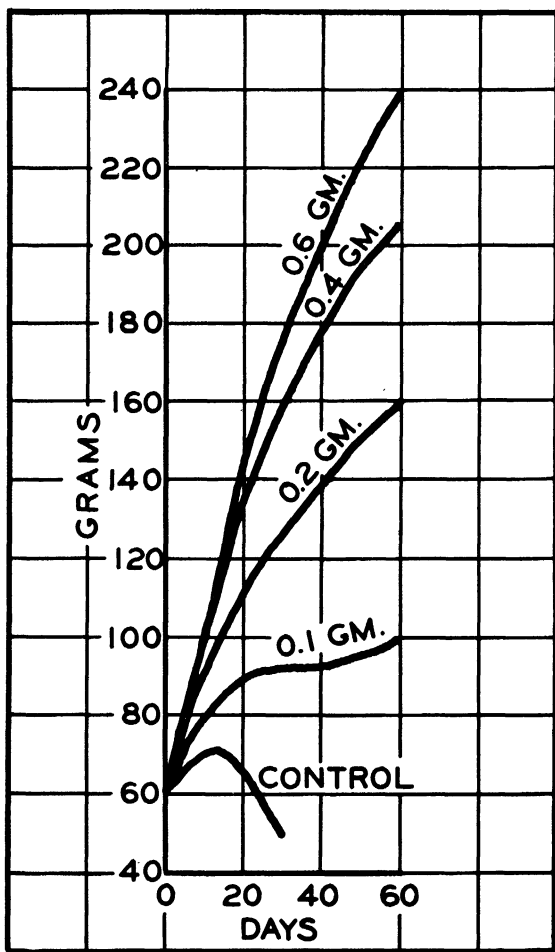


FIGURE 3.—Growth response of rats to different levels of yeast fed as a sole source of vitamin B

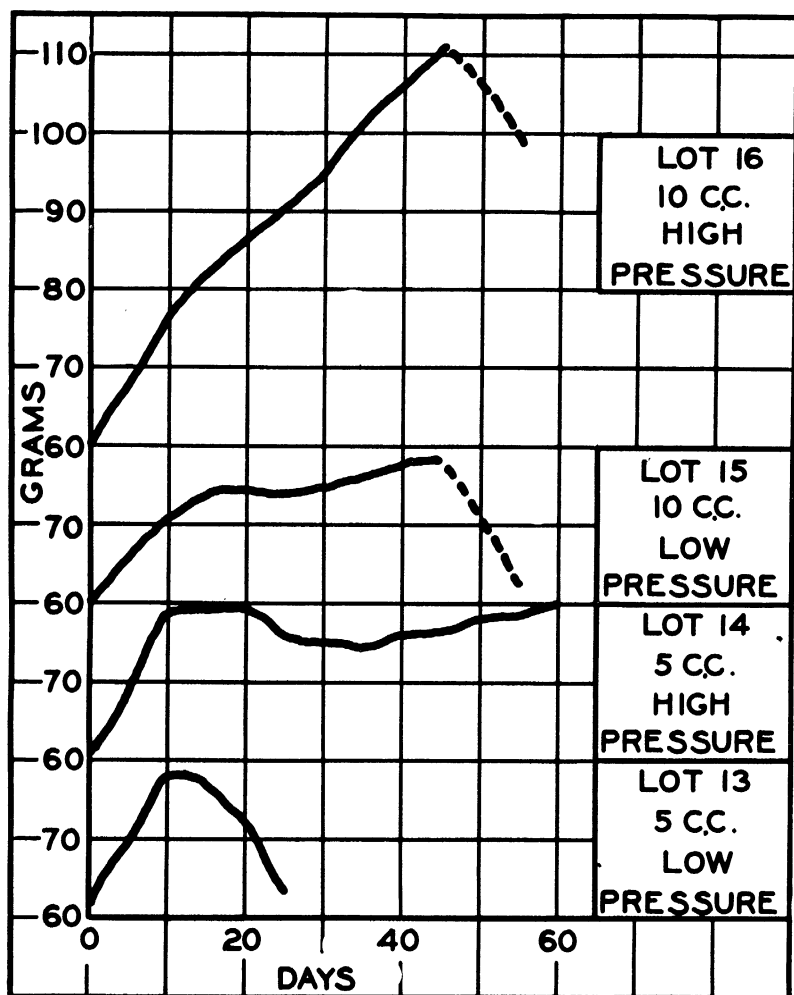


FIGURE 4.—Growth of rats when fed two levels of cane juice expressed at different pressures as a source of vitamin B

TABLE 1.—Analyses of cane juice expressed at high and low pressure

| Item | Cane juice | |
|---------------------------------------|---------------|----------------------|
| | High pressure | Laboratory cane mill |
| Brix.....degrees.. | 18. 60 | 19. 40 |
| Apparent purity.....per cent.. | 71. 23 | 80. 89 |
| Direct polarization.....degrees.. | 13. 40 | 15. 71 |
| Invert polarization.....do..... | -3. 92 | -4. 77 |
| True sucrose.....per cent.. | 13. 95 | 15. 60 |
| Solids (by drying).....do..... | 17. 83 | 19. 01 |
| True purity.....do..... | 78. 24 | 82. 06 |
| Reducing sugars as invert.....do..... | 2. 40 | 1. 65 |

Two rats in lot 13 developed severe polyneuritis at 31 and 38 days, respectively. This symptom of vitamin B deficiency, however, was not observed in the other groups. Further evidence that growth in these experiments was not limited primarily by a lack of the pellagra-preventive factor is presented in the curves of lots 15 and 16. At the end of 45 days when the supply of high-pressure juice was exhausted, these lots received 5 per cent of autoclaved yeast. If the diet of these rats had contained an adequate supply of vitamin B, and growth had been limited by the pellagra-preventive factor, growth at the same rate as that shown for the first 10 days of the experimental period would be anticipated when the autoclaved yeast was added to the diet.

VITAMIN B IN SUGARCANE JUICE FROM THE UPPER AND LOWER THIRDS OF THE CANE STALKS

The upper and lower third portions of the cane stalks (100 pounds each) were run through the laboratory cane mill, and the juice was filtered through two layers of cheesecloth in order to remove finely divided particles of stalk. The top portions yielded 11,840 c. c. of juice, and the lower portions 16,880 c. c.

The juice was concentrated and stored as already described. Analysis of the juice gave the results shown in Table 2.

TABLE 2.—Analyses of juice obtained from the upper and lower third portions of sugarcane

| Item | Juice from upper third | Juice from lower third |
|---------------------------------------------|------------------------|------------------------|
| Brix.....degrees..... | 16.5 | 19.9 |
| Apparent purity.....per cent..... | 81.0 | 90.0 |
| Reducing sugars as invert sugar.....do..... | 1.4 | 0.5 |
| True sucrose.....do..... | 14.04 | 18.13 |
| Solids (by drying).....do..... | 16.73 | 19.58 |
| True purity.....do..... | 83.92 | 92.60 |
| Direct polarization.....degrees..... | +13.55 | +17.93 |
| Invert polarization.....do..... | -4.91 | -5.91 |

As shown in Figure 5, the upper part of sugarcane stalks contains more vitamin B than the lower part of the same stalks. The animals of lots 26 and 28 received juice from the lower third of the stalks, and lots 27 and 29 received juice from the upper third. Each curve represents the average weight of four male rats fed the daily dose indicated at the right of the chart. One rat in lot 26 and two rats in each of lots 27 and 28 failed to survive the experimental period of 60 days. Seven cases of polyneuritis were observed, as follows: In lot 26, two at 38 and 60 days; in lot 27, two at 45 and 48 days; in lot 28, two at 53 days, and one at 56 days.

VITAMIN B IN SUGARCANE CREAM

Sugarcane cream is a new product developed by the carbohydrate division of this bureau.⁷ It is prepared by evaporating cane sirup in an open kettle to a high predetermined density, judged by its boiling temperature; cooling this sirup and crystallizing a portion of

⁷ PAINE, H. S., and BALCH, R. T. SUGAR-CANE CREAM A NEW PRODUCT OF COMMERCIAL VALUE. U. S. Dept. Agr. Yearbook 1927: 605-607. 1928.

the sugar therein with continuous stirring with a "cream beater" similar to that used in making sugar fondant for coated confectionery; and warming slightly the finished cream in a jacketed remelt kettle, in order that the cream may flow into the containers of tin or glass.

Examination of this product for vitamin B was conducted as in the preceding experiments. The cane cream was fed daily apart from the basal diet at the levels indicated in Figure 6. Each curve represents the average weight of four rats. The results show that cane

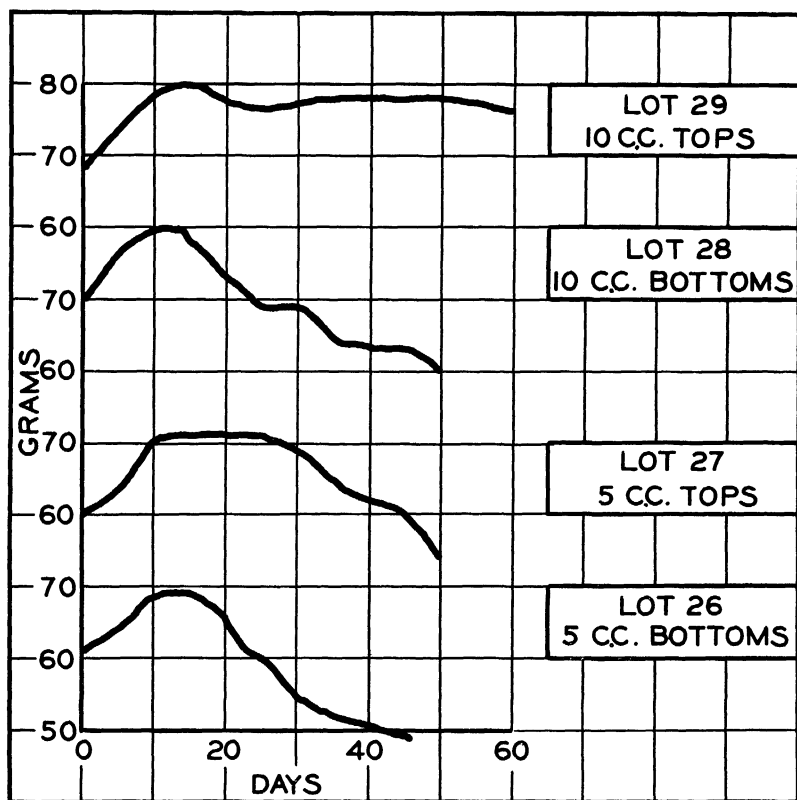


FIGURE 5.—Growth of rats when fed cane juice obtained from different portions of the stalk, as a source of vitamin B

cream contains no vitamin B. The average survival of four male rats in lot 6 was 34½ days; in lot 7, 32 days; and in lot 8, 34 days. Three cases of polyneuritis occurred in lot 6, three in lot 7, and one in lot 8.

VITAMIN B IN SUGARCANE SIRUP AND BLACKSTRAP MOLASSES

Sugarcane sirup and blackstrap molasses were also obtained from the carbohydrate division. The cane sirup had been prepared from sugarcane juice by the Georgia open-pan process. Both Louisiana and Porto Rico blackstrap molasses were examined. Instead of being fed apart from the basal ration as in all the preceding experiments, these products were mixed with dextrin and incorporated in the

ration. The ration was the same as that previously used except that the sirup and molasses replaced an equal weight of dextrin. The average daily intake per animal of the products tested is shown in Table 3, and the growth of the rats fed these products is shown in Figure 7. Each curve in this figure represents the average weight of four male rats. That the products tested did not contain significant amounts of vitamin B is apparent from the fact that no appreciable prolongation of life resulted from their addition to the diet. No case of polyneuritis was observed in lot 56, but in each of the other lots two cases were noted.

TABLE 3.—Average daily intake per animal of cane products tested

| Item | First week | Second week | Third week | Fourth week |
|----------------------------------------|------------|-------------|------------|-------------|
| | Gram | Gram | Gram | Gram |
| Cane sirup..... | 0.41 | 0.43 | 0.33 | 0.24 |
| Porto Rican molasses, 10 per cent..... | .97 | .96 | .63 | .37 |
| Porto Rican molasses, 5 per cent..... | .48 | .56 | .33 | .28 |
| Louisiana blackstrap..... | .54 | .53 | .29 | .26 |

DISCUSSION

Probably the most important practical application of these findings is concerned with the use of cane molasses as a food for both human and animal consumption. During the last 15 or 20 years immense quantities of molasses have been used in the manufacture of so-called molasses feeds. From the results of the earlier work of Nelson, Heller, and Fulmer⁸ it is concluded that there are large variations in the vitamin B content of molasses, since the blackstrap molasses which they investigated was found to be an excellent source of this vitamin, whereas the writers found vitamin B to be absent from two samples of this product.

The results obtained in the present experiments show that the inclusion of generous amounts of molasses in the diet does not insure an adequate amount of vitamin B.

The fact that the upper portion of the cane stalk is richer in vitamin B than the lower portion may be associated with the difference in the

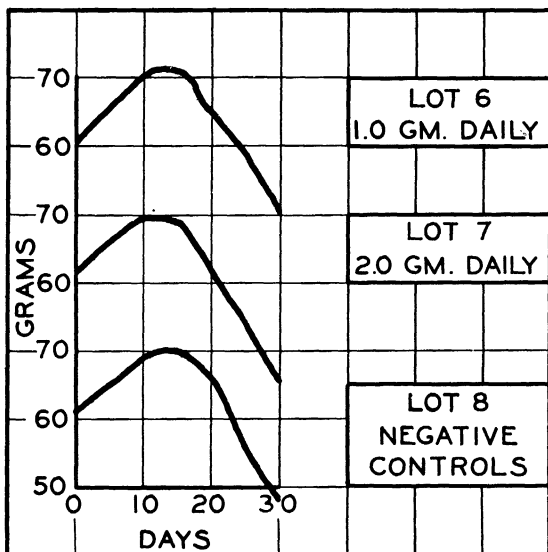


FIGURE 6.—Growth of rats when fed cane cream at different levels as a source of vitamin B

⁸ NELSON, V. E., HELLER, V. G., and FULMER, E. I. MOLASSES AS A SOURCE OF VITAMIN B. *Indus. and Engin. Chem.* 17: 199-201, illus. 1925.

stage of maturity of the different parts of the stalk. The older portion has become a storage organ while the younger portion is still a seat of considerable metabolic activity.⁹ While synthesis of sugar takes place in the leaves and these carbohydrates are then translocated to the stalk, changes in the nature of the sugar in the stalk continue until the stalk reaches maturity.

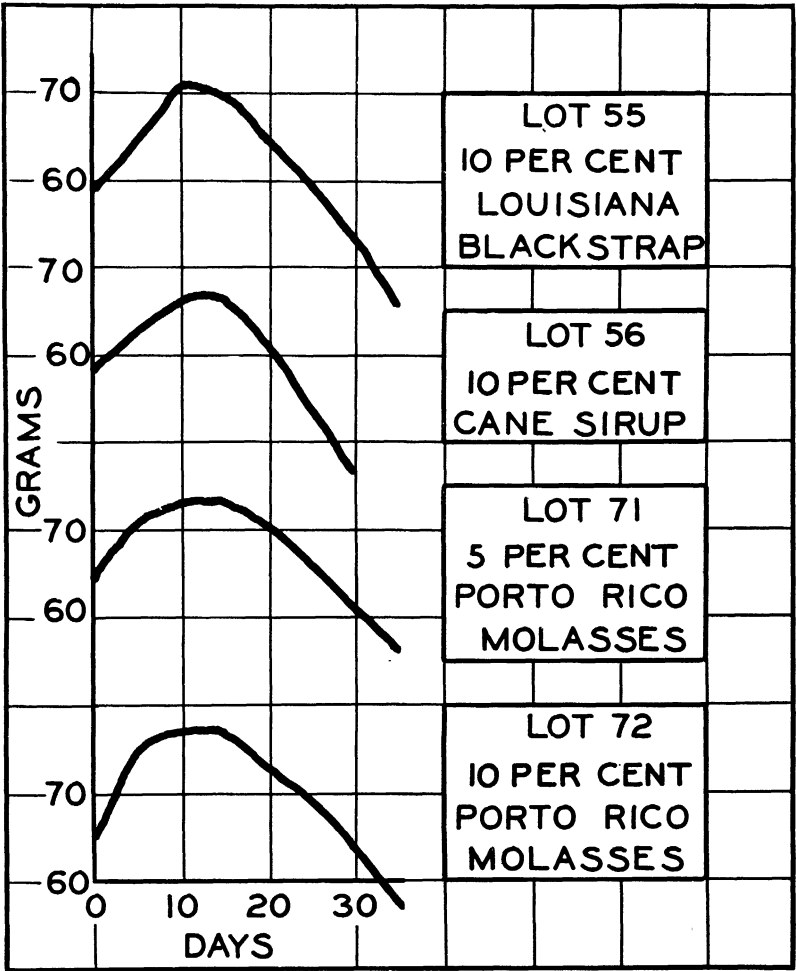


FIGURE 7.—Growth of rats when fed various cane-juice products as sources of vitamin B

Probably the contents of the thin-walled parenchymal cells which contain the sugar are most easily expressed so that the ordinary sugarcane juice does not contain a large portion of other protoplasmic material. By applying much higher pressure the protoplasm of other cells was expressed. The sugar is reserve food for the young plants which develop from the nodes when the stalk comes in contact

⁹ DEERR, N. CANE SUGAR: A TEXTBOOK ON THE AGRICULTURE OF THE SUGAR CANE, THE MANUFACTURE OF CANE SUGAR, AND THE ANALYSIS OF SUGAR-HOUSE PRODUCTS. Ed. 2, rev. and enl., 644 p., illus. London. 1921.

with the ground or is buried in it. It seems that there is more vitamin B in those cells in which there is the greatest metabolic activity.

SUMMARY

The results of studies of the vitamin content of sugarcane juice and some commercial products made from it are reported.

Sugarcane juice is a poor source of the antineuritic vitamin. The juice from the upper portions of cane stalks is richer in this vitamin than juice from the lower portions. Juice obtained from bagasse by using high pressure is richer in the antineuritic vitamin than ordinary cane juice.

Sugarcane juice contains a small amount of vitamin A and little, if any, vitamin D.

Cane sirup, Louisiana and Porto Rico blackstrap molasses, and cane cream, products made from sugarcane juice, were found to be devoid of demonstrable quantities of vitamin B.

